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The Challenge of Offshore Drilling in the Arctic

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The paper presents the challenges of offshore drilling in the Arctic region and the need for research in this area. The author discusses the physical and technical challenges of drilling in the Arctic and the need for research in this area.

THE CHALLENGE OF OFFSHORE DRILLING IN THE ARCTIC

Contributed by the Petroleum Division of the American Society of Mechanical Engineers for presentation at the Energy Technology Conference & Exhibition, New Orleans, La., February 3-7, 1980.

by A. Muraszen

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The Challenge of Offshore Drilling in the Arctic

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The paper will evaluate offshore drilling technology for Beaufort Sea. Environmental impact of offshore activities, mitigating measures, and gaps in the technology will be discussed.

THE CHALLENGE OF OFFSHORE DRILLING IN THE ARCTIC

Arctic Offshore Environment

The offshore hydrocarbon reservoir of Alaska which in the Arctic region is located in the Beaufort and Chukchi Seas may be substantial. According to the 1975 USGS estimates of statistical means, the onshore Alaska undiscovered recoverable oil reservoirs are pegged at 12 billion barrels and offshore at 15 billion barrels. The onshore gas reserves are estimated at 32 trillion cubic feet and the offshore at 44 trillion cubic feet. This in today's energy market is a strong incentive for development of the Alaskan offshore reservoirs and if the exploratory drilling after the forthcoming lease sale prove encouraging, the Beaufort and Chukchi Seas may witness engineering activities under the most challenging conditions that nature can muster.

Among the potential problems of the Beaufort and Chukchi Seas offshore developments climate, ice, remoteness, and environmental sensitivity are probably the most important.

Temperatures of minus 15°F to minus 20°F in mid-winter are typical with wind chill factors to minus 60°F and below at times. Winds of 10 to 15 mph throughout the year are frequent and such winds coupled with an air temperature of minus 15°F can freeze exposed flesh within one minute. Figure 1 shows monthly temperature averages including chill factors for Barrow, Alaska. Skies are cloudy 60 percent of the year and fog occurs between 30 and

100 days annually in coastal areas. Twenty four hour darkness during two to three months of the year and other phenomena, such as optical haze, whiteout, and snow blindness add to the difficulties of any operation.

Ice covers the Beaufort and Chukchi Seas during 9 to 10 months per year. Near shore ice-free waters suitable for marine transport are usually available only in August and September. The ice can be divided into the landfast zone, grounded ridges (Stamukhi) and the ice pack. These zones are shown in Figure 2. The landfast ice which grows to 5 to 6 ft thick during a winter is grounded near shore and is subjected to pressures of the moving ice pack. As a result of this pressure and of tremendous shear forces exerted, ice ridges are formed, many of them grounded in 40 to 60 ft water depth. The landfast ice close to the shore is reasonably stable during winter but during a freeze-up and thaw-up, considerable movement takes place. Table 1 gives some data of ice movement in various ice zones.

Ice scouring the sea bottom is another aspect of the Beaufort Sea and is caused by grounded ice ridges. The depth and frequency of the scour is very much a function of location and Table 2 provides a few published data. More data, no doubt, are being obtained now in industry funded studies.

Remoteness of the Arctic offshore from urban and industrial centers combined with lack of roads, airports and with limited marine transportation puts heavy emphasis on logistics support and need for advanced planning, with contingencies provided against Murphy's law. Table 3 summarizes the problems of Arctic logistics support and transportation.

The terrestrial and marine biota of the Arctic is fragile and small disturbances may require a long healing process. Thus, there will be emphasis on application of the best technology in prevention of oil spills, in quick oil containment and disposal if they occur, in careful waste disposal plans, and in

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planning operations in a manner which would minimize the environmental impact.

A few words now about the coastal bathymetry of the Beaufort and Chukchi Seas continental shelf. The Beaufort Sea shelf is relatively narrow averaging 50 miles in width and it breaks at 230 to 250 ft water depth. The bottom slope is gentle and the 66 ft isobath which is the perimeter of the forthcoming lease sale is between 11 to 45 miles offshore.

The Chukchi Sea shelf has similar characteristics with gentle slope gradient and with the 66 ft isobath lying an average of 10 miles offshore.

The geology of the sea bottom was studied under OCSEAP program and indicates that surface sediments are very diverse and range from over consolidated clays to boulders with predominance of poorly silted clays and sandy muds. In some areas coarse grained sediments (sand and gravel) important for artificial island construction are found beneath 25 to 35 ft overburden of mud and silt.

Arctic Offshore Drilling Technology

I will discuss two phases of offshore drilling; the exploratory phase and the field development and production phase. Exploratory drilling has been conducted for the last few years in the Canadian Arctic offshore by the Imperial Oil, Ltd. (recently renamed Esso Resources Canada - ERC), by Panarctic Oils, Ltd. and by Dome Petroleum, Ltd. In the Alaskan Beaufort Sea exploratory drilling was less intensive and was carried out by Sohio (BP), Union Oil and Exxon. The three main types of drilling platforms used in the exploration were; artificial sand/gravel islands, ice platforms and drillships.

Artificial islands were by far the most numerous and most of them were built by ERC as shown in Table 4. The shallow waters of MacKenzie Delta were particularly suited for the ERC islands as would be the shallow waters of the Beaufort Sea. The deepest water in which an artificial sand/gravel island was recently completed by ERC was at approximately 60 ft.

Artificial islands have been built in both summer and winter. In summer the fill material was obtained offshore by dredging near the site or by transporting by barges if the offshore source was a distance away. In winter construction the fill material was transported over ice by trucks and dumped at the island site. As can be seen from Table 4 the amount of fill required for an artificial island with a working area of 2 to 2 1/2 acres may run into millions of cubic yards, consequently the cost per cubic yard is an important item in island construction. This cost can vary from \$2/cu yd with the fill available at site to \$30/cu yd with the fill some distance away.

In the design of an island, consideration should be given to ice forces, to ice override, and to wave erosion and overtopping. Figure 3 identifies three modes of a possible island failure when large ice forces are applied.

To avoid ice override, islands are usually built with gentle slopes which can break-up and stop invading ice far enough from the work area.

To mitigate wave erosion island shore protection is provided in the form of small and large sandbags, gabions, and sacrificial beaches as shown in Figure 4. Fortunately, storm waves in the Beaufort Sea are not very high and in general a 25 ft wave is considered as a 100 year maximum

to be expected.

There were also artificial islands built in the Beaufort Sea. Sohio (BP) built two islands in the Sag River Delta in 3 ft and 10 ft water depth and Exxon built an island in 4 ft of water near the Duck Island.

The experience with all the islands built was quite satisfactory and no failure of any kind has occurred. Instrumentation was usually provided to record any shifting of an island, to record movement of surrounding ice and temperature of island fill.

Any environmental impact of an artificial island occurs mainly in the construction phase and is related to the removal and dumping of fill which temporarily increases water turbidity and displaces and destroys some benthic organisms. Once an island is built it may actually have a beneficial effect on the marina biota by offering a shelter from waves and currents.

Drilling ice platforms are formed by artificially thickening the natural ice. This concept limits, therefore, drilling to a winter season between February and April. Panarctic Oil built a number of ice platforms in water depths of 200 to 1,300 ft in the exploration of the Sverdrup Basin of the Canadian Arctic islands.

Figure 5 shows a schematic of such a floating ice platform. As can be seen, the ice was built up to a thickness of 16 ft and the critical parameter in the construction of an ice platform was ice deflection under its own load and the load of the drilling equipment. In addition to an instantaneous deflection under a load there was a creep deflection continuing with time. Flexural stresses in the ice must be kept low enough so that at the end of the drilling season an ice platform still has some freeboard height relative to the surface of the surrounding ice.

The main criterion for possible use of ice platforms is small movement of the surrounding ice during a drilling season so as not to endanger the integrity of the riser. In Panarctic drilling locations the ice movement was less than 10 ft during a winter season.

Such conditions do not exist in most of the potential exploratory areas in the Beaufort Sea, consequently, this concept may not be useful.

An alternative to deep water floating ice platforms are grounded ice platforms in shallow waters such as were built by Union Oil in 10 ft water depth in the East Harrison Bay.

Figure 6 shows a location and cross section of such an ice platform. To guard the platform against the movement of surrounding ice a protective grounded ice ring of 1,000 ft diameter was built which could also act as a berm containing the oil in case of an oil spill. Additional protection against ice movement was provided in the form of a 10 ft wide moat kept free of ice during the drilling season.

As in the case of artificial sand/gravel islands the ice platform concept was quite successful in exploration work.

The environmental impact of ice platforms is negligible since they melt and disappear during the summer season.

Finally a few words about drillships. Dome Petroleum carried out exploratory drilling north of the MacKenzie Delta in water depths of approximately 200 ft. The Canadian fleet consisted of three drillships with reinforced hulls, seven

Class II icebreaker supply boats, three barges and one ocean-going bulk carrier. There was a reported case of uncontrolled gas and water well caused by sudden ice intrusion and drillship displacement. The drilling season was limited to 45 days to comply with Canadian Regulations and that made drillship operations quite expensive.

It is unlikely that either drillships or semi-submersibles would be used in near-future exploration in the Alaskan Beaufort Sea because of the shallowness of water (depth up to 66 ft) in the areas earmarked for forthcoming lease sale.

Thus, for near future exploratory drilling in the Alaskan Beaufort Sea, artificial sand/gravel islands, grounded ice platforms in shallow waters, sunken barges with reinforced hulls, or some of the natural islands will most likely be used.

The development and production phase would require permanent structures which could operate safely for 20 to 30 year periods. Various concepts are being considered by the industry but only a few will be mentioned here.

A foreseeable evolution of temporary artificial sand/gravel island would consist of reinforcement of island slopes to withstand the onslaught of waves and ice. Such a caisson-retained island shown in Figure 7 was proposed by ERC. It consists of eight trapezoidally shaped steel caissons 141 ft long, 40 ft high with a base of 43 ft. The space contained within the octagon is filled with sand and gravel of sufficient bearing strength to support the drilling and production equipment. The design water depth is 30 ft with 10 ft freeboard. For deeper water location it is necessary to build an underwater berm of sufficient height to maintain the required freeboard. One of the advantages claimed for a caisson-retained island is a saving in fill requirement as compared to the islands discussed before. For instance, for a water depth of 30 ft the caisson-retained island would require only 1/10 of the fill of a sacrificial beach island.

Grounded barges which were used by Sun Oil, Ltd. in exploratory drilling could be considered for long term operations when built for that purpose with sufficient deck area and reinforced hulls. Such a barge was proposed by the Offshore Company and is shown in Figure 8. The barge would be protected against wave erosion and ice invasion by the reinforced hull overlain by gabions or concrete blocks.

Conical structures (single or dual cones) are being studied by several companies such as Exxon, Chevron, ERC and Dome. If developed in time they could be used in exploratory drilling as well as in the production phase. A monocone proposed by ERC is shown in Figure 9. This particular design was suitable for water depth from 55 to 135 ft. Another design of dual cone by Chevron could be installed in shallower waters down to 10 ft depth. The basic reason for a conical design at the ice interface is to break the ice in flexure rather than in compression. To prevent the ice adfreeze to the surface of the cone, it would be heated.

Another concept is a monopod and Figure 10 shows a design proposed by ERC.⁶ The structure made of steel consists of three parts: the hull, the column and the superstructure. Once on location the hull is ballasted with water and set down in a prepared excavation in the seabed so that the hull is totally concealed and only the relatively slender column is exposed to ice loading

(Brown, 1976). The design was for water depth varying from 10 to 40 ft.

Cones and monopods are mobile units and therefore could be considered also for exploratory drillings if their availability is timely and the economics competitive with other systems.

In summary, there are various options open to development and production of hydrocarbon reservoirs in the Beaufort and Chukchi Seas, such as: barrier islands (if environmentally acceptable), reinforced artificial sand/gravel island, reinforced-hull grounded barges, and cones, monopods structures.

There will also be probable application in the Arctic offshore for subsea completion systems, both BOP's and Christmas trees. Subsea BOP's were used by Dome and Panarctic in the Canadian exploration and will probably be used in any mobile system in the Alaskan Arctic. The subsea Christmas trees might be used in peripheral wells connected with gathering lines to a central platform. All subsea units must be placed deep enough below the mud line to avoid the ice scour hazard.

Economics of Arctic Offshore Operations

The cost of Arctic offshore drilling operation is difficult to review because the published data are scanty and the unpublished are proprietary. However, some data were collected to give the reader an idea of costs involved.

Drilling in the Arctic offshore is expensive and Panarctic estimated that Arctic offshore drilling is about 10 times the cost of drilling in more temperate climates. Panarctic wells drilled from ice platforms cost \$2.5 to \$4 million (1976 dollars). Exxon estimated the cost of an exploratory well from a sand/gravel island at \$18 million.

Drilling from ships was the most expensive because of the shortness of the drilling season and the employment of a number of expensive vessels. Dome estimated the cost at \$30 million per well.

For sand/gravel islands listed on Table 1 the cost varied from \$1 to \$15 million, the cost being a strong function of the availability of fill and of water depth.

Ice platforms were the least expensive and Union Oil estimated that their grounded ice platform cost 1/4 of an artificial sand/gravel island at the same water depth.

The permanent structures would be, of course, more costly. The caisson reinforced island was estimated at \$27 million and a monocone at \$50 to \$80 million.

The subsea completed BOP used by Panarctic cost approximately \$1 million.

Yet, while the cost of drilling operations in the Arctic offshore is high, the escalating cost of energy will assure that if any oil or gas is found there in sufficient quantities, it will be extracted.

Overview of Hazards to Arctic Offshore Drillings

In discussion of hazards of Arctic offshore to drilling operations, I'll cover a few main areas indicating also the mitigating measures that could be applied to reduce the hazard.

Climatic. Sub-zero temperatures prevailing in the Arctic offshore most of the year when combined with frequent winds, whiteouts and fog, make

any outside activities difficult and hazardous. Human efficiency is reduced, susceptibility to error is increased, materials become brittle, field welding and pipe bending operations require special preheaters. All such problems can be overcome as evidenced by the onshore construction of the 800 mile long Trans-Alaska oil pipeline and an offshore gas pipeline of Panarctic in the Canadian Arctic Islands.

Oceanographic. Waves and currents should not pose a serious problem in the Beaufort or Chukchi Sea. There are no reliable data on extreme waves and currents but from past observations recorded it is apparent that a 100 year wave would not exceed 20 - 25 ft and extreme currents 3 - 4 knots. Experience with offshore structures in the Gulf of Mexico, North Sea or Cook Inlet provided more than a sufficient technological base to deal with such hazards.

Artificial sand/gravel islands have to be protected against slope erosion and wave overtopping, but experience acquired in exploratory islands pointed the way to slope protection measure and freeboard requirements. Permanent artificial islands have yet to be built in the Arctic but the question is not whether they could be built but what would be the most economic solution, and what would be the trade-off between more solidly (and most costly) built islands with lower maintenance, versus less expensive ones with a higher amount of maintenance.

Ice. The presence of ice in Arctic waters brings forth a series of problems not encountered in temperate climates. Ice covers the surface of the Beaufort Sea about 80 percent of the year and hazards are related to the movement of masses of ice and to the ice scouring the sea bottom.

Ice moving against a structure attached to the sea bottom will exert force either by compression eventually crushing the ice or by shear and ice failure in bending. Ice forces may also vary with time and induce dynamics vibrations to offshore structures. Failure of some braces was reported in Cook Inlet platforms and a lighthouse in Finland failed due to ice caused vibrations. Ice strength is a function of ice characteristics and of structure size and shape and no one value for ice compression or flexure strength could be given. Typically, for large structures in saline ice, the ice crushing strength would be of the order of 300 to 500 psi and flexure strength of the order 100 to 150 psi. The lower flexural strength of ice is the reason for conical configuration for some proposed offshore platforms. For instance, the calculated ice force on a 100 ft diameter cone would be (without consideration of an adfreeze) approximately 30,000 kips (Jazrawi, 1977).

Ice scouring phenomenon, already discussed before, poses a hazard to underwater pipelines, BOP's or any other equipment. Thus, underwater pipes and valves must either be buried below the scour depth or provided with some other protective means.

Permafrost. The presence of subsea and nearshore permafrost in the Beaufort Sea was confirmed (Weeks et al., Barner and Hopkins, OCSEAP Report 1978). Bottom formed structures must consider it in the foundation design to over-

come the problem of permafrost thawing and possible subsidence.

Permafrost may also affect dredging operations, well drilling, and pipe laying. Considerable experience with well drilling in permafrost was accumulated in the Prudhoe Bay development and a series of papers were written on means of protection of well casings in case of thaw subsidence or refreeze (for instance, Goodman, 1977-78). Hot oil pipes must be protected against sagging or designed for it if they cross ice-rich high pore pressure permafrost areas.

The technology to deal with this problem is available provided the location of permafrost pockets and its characteristics are predetermined from geological investigations.

Oil Spill. The possibility of an oil spill occurring during drilling operations and a loss of well control cannot be disregarded. It is true that the probability of a oil well blowout is small. It is also true that if it happens, it is mostly during the development and production phase and rarely during exploratory drilling.

Nevertheless, however small may be the possibility of a major oil spill in any of the phases of oil drilling, it has to be considered and prior contingency plans should be made to cope with it.

The problem of oil spill in ice covered waters was studied by various researchers and Energy Interface Report, 1979 provides a listing of major studies. The containment of the spilled oil and its environmental impact depends greatly on the season. In winter when the oil is spilled on ice or snow-covered ice it is probably the easiest to contain and dispose of by burning or other means. Oil spilled under ice will be subjected to gravitational and viscous forces and form a thick layer of 0.25 in. or more, collecting in cavities below the ice in a relatively small area. Lewis (1976) calculated that in a well blowout lasting one year, oil under ice would be accumulated within about one mile radius from the well. By drilling through the ice the oil could be pumped out and disposed of. The environmental impact of spill under ice will probably be slight. Seals, plankton, and fish would suffer if exposed to the oil but no significant numbers would be involved.

The major problem would occur if the oil is not collected by the time the spring thaw begins. As the ice melts, oil would float to the surface, be dispersed by spring run-offs at river mouths or would be transported great distances in the still unmelted ice floes. Impact of the oil could then be more serious affecting migrating birds, whales, fish, and plankton.

Spill during summer in ice-free water is not different with regard to containment and disposal from a spill in more temperate climates. The environmental impact of oil dispersed by wind and currents may be significant as it was in the spring. On a longer time scale some of the oil would sink and become incorporated into bottom sediments affecting the benthic organisms.

What countermeasures can be employed? Probably the best countermeasure is pre-planning. This is particularly true for the Arctic because of its remoteness and the difficulty of accessibility discussed before. Contingency plans to deal with an oil spill in various locations and occurring during various seasons should be prepared in

advance, defining responsibilities and the participation of industrial, state and federal agencies involved; defining technology and strategy to be used for well control, oil containment and disposal; defining the need and availability of equipment and manpower.

The Ixtoc well in the Campeche Bay took several months to control because, amongst other reasons, there were no adequate contingency plans. How much more time would be needed to control a wild well in the Beaufort Sea if similar situation would exist?

Conclusions

Technology for exploratory drilling in Arctic offshore is available. Construction of permanent structures for field production is in the design stage and some proofs of the concept would be desirable.

There are still data gaps regarding ice movement, storm waves, storm currents and permafrost location and characteristics. Industry is funding research in these areas but data may remain proprietary for a number of years.

Consideration of a major oil spill in the Arctic offshore should receive, and I believe is receiving, early and serious attention by the governmental and industrial organization involved. Detailed and realistic planning against a possible spill or well blowout, and prearrangement for availability of needed equipment will always be less expensive when done in advance of thaw during an emergency and may prevent far reaching consequences of a drilling mishap.

An industry which possesses the knowledge, experience and data of the Arctic environment and mitigating measures should not keep them hidden under the cloak of confidentiality, but should share some of this knowledge with those to whom the Arctic environment is precious. It is the shared knowledge and not ignorance that can bridge the credibility gap between the industry and the public at large.

References

To avoid repetition, the following abbreviations have been used throughout these references:

NOAA	National Oceanic and Atmospheric Administration
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OTC	Offshore Technology Conference
POAC	Port and Ocean Engineering Under Arctic Conditions

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Figure 1. Equivalent Chill Temperature at Barrow, Alaska—Percent Probability of Occurrence (Searby & Hunter, 1971)

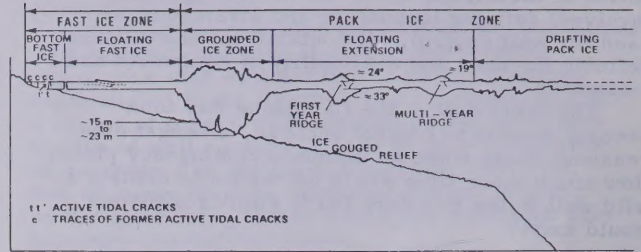
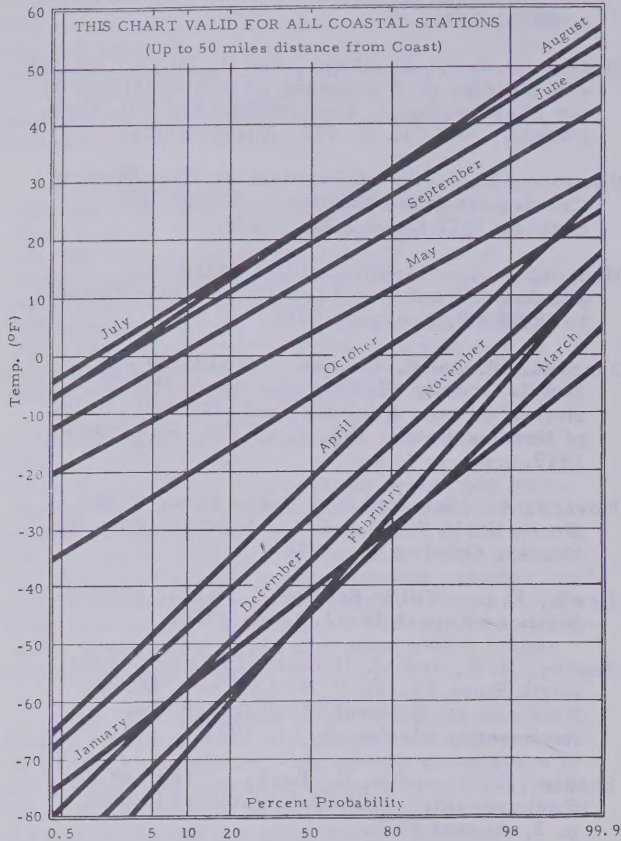


Figure 2. Late Winter Ice Zonation of the Alaska Beaufort Sea (Shapiro & Barry, 1978)

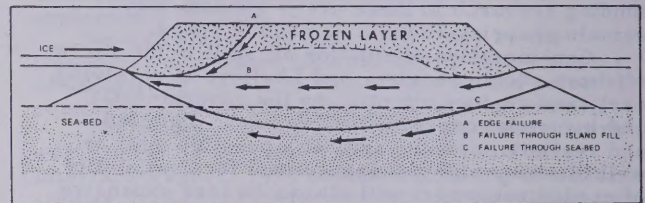


Figure 3. Possible Failure Planes of an Artificial Island (de Jong, 1975)

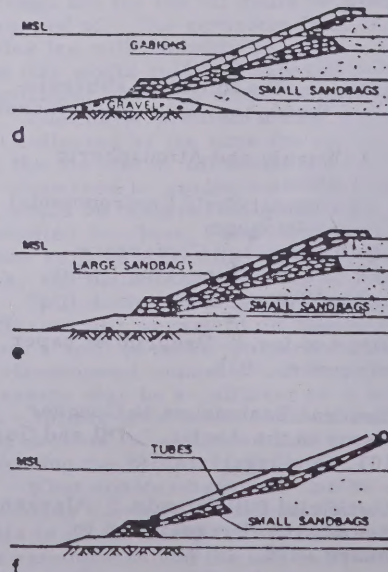
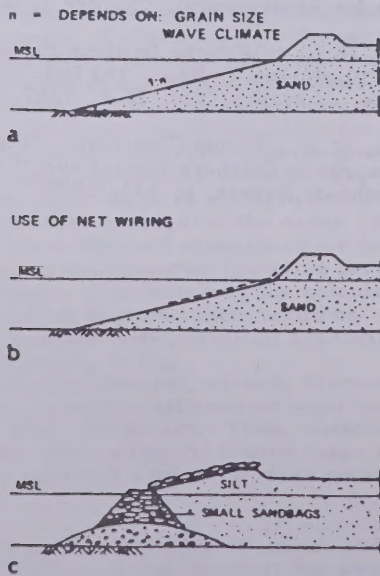


Figure 4. General Design of Shore Protection for Artificial Islands (de Jong, 1975)

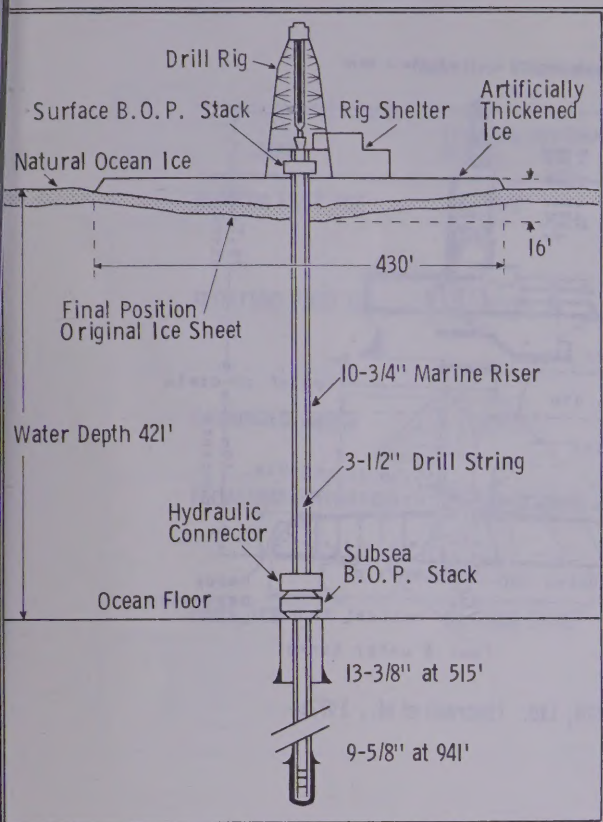
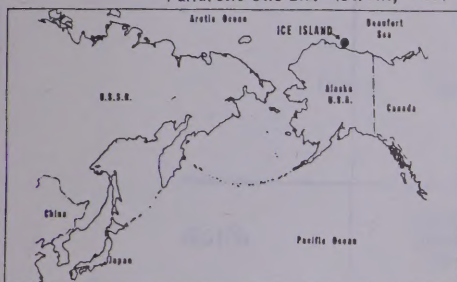


Figure 5. Schematic Diagram of Ice Platform Offshore Drilling System, Panarctic Oils Ltd. (Strain, 1975)



LOCATION

SCHEMATIC

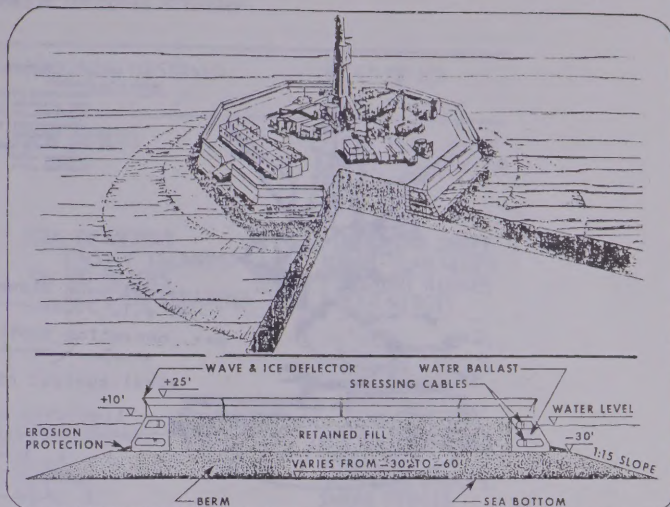
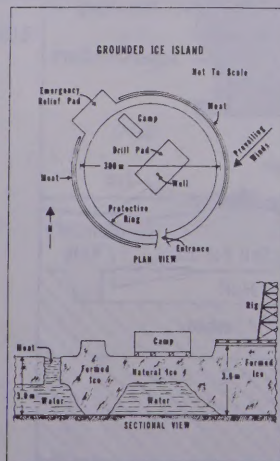
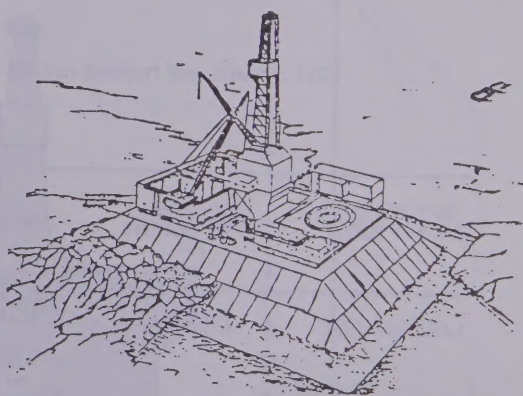


Figure 7. Caisson Retained Island, Imperial Oil (de Jong, 1978)



OPERATING W. D. : 6' MINIMUM
30' MAXIMUM
HULL DIMENS. : 288' X 308' LOWER
120' X 200' UPPER
36' DEPTH
6' ADDITIONAL POSTED HEIGHT

Figure 8. Grounded Barge Island (Hudson, 1978)

Figure 6. Grounded Ice Island, Union Oil, 1976-77 (Brinker, 1978)

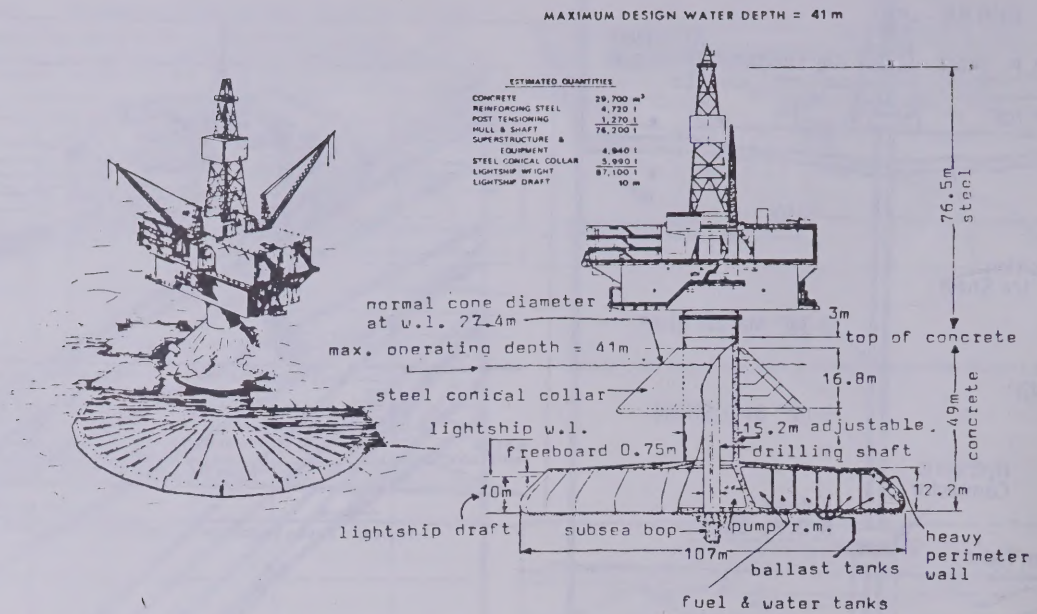


Figure 9. Monocone Drilling Rig 41, Imperial Oil, Ltd. (Jazrawi et al., 1977)

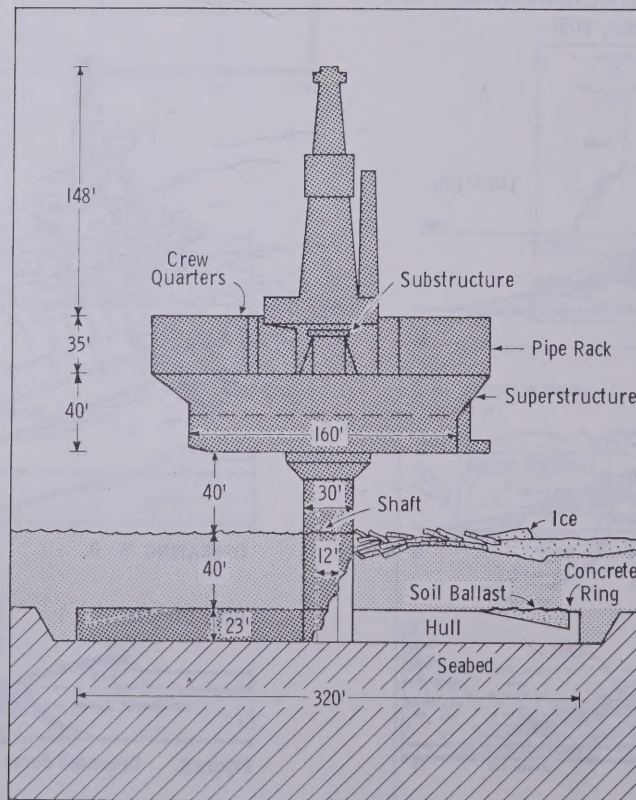


Figure 10. Monopod Drilling Unit (Brown, 1976)

Table 1. Characteristics of Ice Zones in Winter

ZONE	TYPICAL DEPTH RANGE (M)	MAXIMUM OBSERVED MOTION	TYPES OF ICE
BOTTOM FAST ICE	0-2	FEW METERS	FIRST YEAR SHEET SMALL MULTI-YEAR FRAGMENTS
FLOATING FAST ICE	2-15	TENS OF METERS (INSIDE ISLANDS) > 100 METERS (OUTSIDE ISLANDS)	FIRST YEAR SHEET MULTI-YEAR FLOES PRESSURE RIDGES SHEAR RIDGES
GROUNDING RIDGE	15-23	?	PRESSURE RIDGES SHEAR RIDGES
FLOATING EXTENSION	23-SHELF EDGE	> KM/DAY	MULTI-YEAR FLOES SHEET ICE PRESSURE RIDGES SHEAR RIDGES
PACK ICE	BEYOND SHELF	> KM/DAY	MULTI-YEAR FLOES PRESSURE RIDGES ICE ISLANDS SHEAR RIDGES

Table 2. Ice Scour Zones in the Alaskan Beaufort Sea (Kovacs, 1972)

REGION	WATER DEPTH (M)	TYPICAL SCOUR DEPTH (M)	MAXIMUM SCOUR DEPTH (M)	FREQUENCY OF SCOUR TRACKS
COASTAL SHELF	0-7	< 0.5	NO DATA	VERY FREQUENT
MID-SHELF	7-30	< 1.5	3-4	10-15/KM
OUTER SHELF	30-80	NO DATA	10	SLIGHT BEYOND 45 METER DEPTH

Table 3. Logistics Support in the Arctic

TYPE	EXAMPLES	CONCERNS	TECHNOLOGY NEEDS	DATA NEEDS
MARINE	● SURVEY SHIPS ● SUPPLY BARGES	● SUMMER ICE ● OPER. COST ● HAZARDS	_____	● IMPROVED ICE FORECASTING
ICE SURFACE	● TRUCKS ● SLEDS ● ROLLIGON	● ICE THICKNESS ● SNOW DRIFTING ● ICE MOVEMENT RIDGING	● RIDGE-CROSSING TECHNIQUES	_____
AIR	● FIXED-WING ● HELICOPTER	● RUNWAY ● WEATHER ● DOWNTIME COST	_____	_____
AMPHIBIOUS	● ACV	● RELIABILITY ● ICE RIDGE CROSSING	● IMPROVED RELIABILITY ● INCREASED GND. CLEARANCE	_____
ALL-WEATHER YEAR-AROUND	● CAUSEWAYS	● ICE PRESSURE ● ICE OVERRIDE ● WAVE EROSION ● GRAVEL AVAIL. ● MARINE BIOTA	_____	● ICE PRESSURE OVERRIDE ● OCEANOGRAPHIC ● BENTHIC LIFE

Table 4. Beaufort Sea Artificial Sand Islands (Cox, 1978)

Company	Name	Year	Water Depth	Type of Construction	Surface Size	Freeboard	Construction	Fill	Cost	Type
			FT.		FT.	FT.	DAYS	CLUSTERS	\$MM	
Imperial Oil Sun Oil	Immerk B-48	*73S	10	Dredge and Pipeline	300 dia	15	110	240m	5	Sac. Beach
	Adgo F-28	*73S	7	Clamshells	150x600	3	30	48m	2.5	Sandbag Ret.
	Pullen E-17	*74Sp	5.5	Trucks Over Ice	225x375	10	45	84.5m	3	Sandbag Ret.
	Unark L-24	*74Sp	3.5	Trucks Over Ice	200x400	8	50	57m		Sandbag Ret.
	Pelly B-35	*74S	7.5	Barge Core and Clamshell	270x515	6	50	45m		
Imperial Oil	Netserk B-44	*74S	15	Dump Barges and Clamshells	320 dia	15	80	400m	11	Sandbag Ret.
	Adgo P-25	*74S	5	Clamshells	225x470	2	30	36m	2.5	
	Adgo C-15	*75W	5.5	Trucks Over Ice	165x515	10	42	92m	3	
	Netserk F-40	*75S	23	Dump Barges and Clamshells	320 dia	15	100	380m	15	Sandbag Ret.
	Sarpik B-35	*76Sp	13.5	Trucks Over Ice	320 dia	22	44	155m	5	
	Ikkatok J-47	*76S	5	Flat Barges and Clamshells	150x425	7	30	50m		
	Arnak L-30	*76S	28	Dredge and Pipeline	320 dia	17	35	1.5mm	5	Sac. Beach
	Kannerk G-42	*76S	28	Dredge and Pipeline	320 dia	17	30	1.5mm	3	Sac. Beach
	Kugmallit D-49	*76S	17	Dump Barges and Clamshells	320 dia	15	37	310m		Sandbag Ret.
Sohio	Adgo J-27	*76S	6	Clamshells	165x350	10	30	90m		
	Isserk	*77S	43	Dredge and Pipeline	320 dia	15	80	2.5mm		Sac. Beach
	Sag Delta	*77W	3	Trucks Over Ice	325x400	4	14	52m	1	
S-SUMMER			W-WINTER			Sp-SPRING			m = thousands (10 ³) mm = millions (10 ⁶)	

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CANADA

TABLE 1				
Year	1950	1951	1952	1953
1. Total population	1,000,000	1,050,000	1,100,000	1,150,000
2. Total population	1,000,000	1,050,000	1,100,000	1,150,000
3. Total population	1,000,000	1,050,000	1,100,000	1,150,000
4. Total population	1,000,000	1,050,000	1,100,000	1,150,000
5. Total population	1,000,000	1,050,000	1,100,000	1,150,000
6. Total population	1,000,000	1,050,000	1,100,000	1,150,000
7. Total population	1,000,000	1,050,000	1,100,000	1,150,000
8. Total population	1,000,000	1,050,000	1,100,000	1,150,000
9. Total population	1,000,000	1,050,000	1,100,000	1,150,000
10. Total population	1,000,000	1,050,000	1,100,000	1,150,000

TABLE 2				
Year	1950	1951	1952	1953
1. Total population	1,000,000	1,050,000	1,100,000	1,150,000
2. Total population	1,000,000	1,050,000	1,100,000	1,150,000
3. Total population	1,000,000	1,050,000	1,100,000	1,150,000
4. Total population	1,000,000	1,050,000	1,100,000	1,150,000
5. Total population	1,000,000	1,050,000	1,100,000	1,150,000
6. Total population	1,000,000	1,050,000	1,100,000	1,150,000
7. Total population	1,000,000	1,050,000	1,100,000	1,150,000
8. Total population	1,000,000	1,050,000	1,100,000	1,150,000
9. Total population	1,000,000	1,050,000	1,100,000	1,150,000
10. Total population	1,000,000	1,050,000	1,100,000	1,150,000

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